

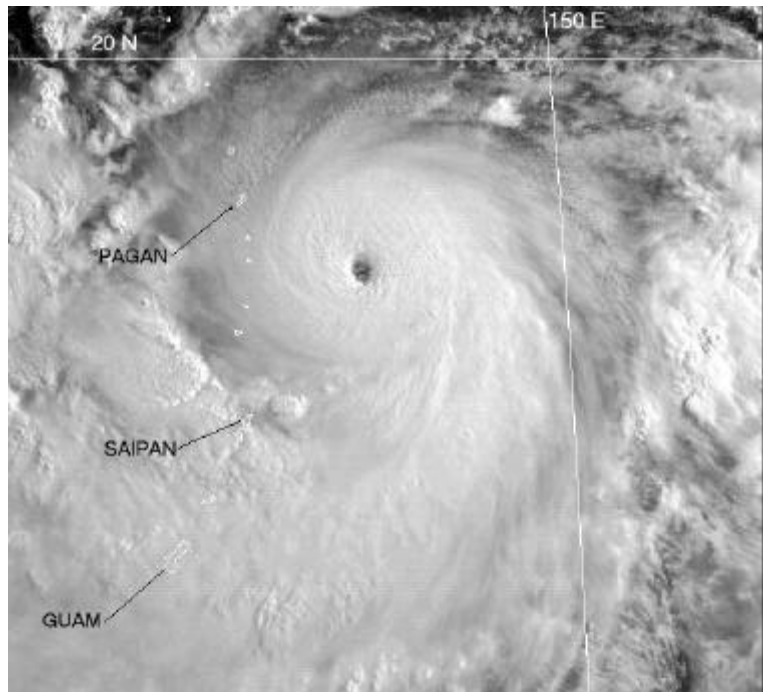
SUPER TYPHOON WINNIE (14W)

I. HIGHLIGHTS

Winnie formed at low latitudes in the Marshall Islands and was the fourth of eleven tropical cyclones (TCs) to attain super typhoon intensity in the western North Pacific during 1997. It was one of ten TCs that formed east of 160E and south of 20N; the "El Niño" box in Figure 3-3a. Winnie was a straight running TC that passed over Okinawa, and later made landfall on the eastern coast of China, where it was responsible for loss of life and considerable damage. When it was near Okinawa, the typhoon formed concentric eyewall clouds. The 200 nm (370 km) diameter of the outer eyewall cloud, observed by satellite and radar, was one of the largest ever recorded.

II. TRACK AND INTENSITY

During the first week of August, two TCs, Tina (12W), and Victor (13W), moved northward in the western portion of the West North Pacific (WNP) basin. Concurrent with the evolution of these TCs, an area of deep convection associated with the El Niño related low latitude westerly wind flow east of 160E persisted near the Marshall Islands. The disturbance was added to the 5 August Significant Tropical Weather Advisory (ABPW) after satellite imagery and synoptic data indicated a low-level cyclonic circulation with sea-level pressure in the region approximately 2 mb below normal.



The monsoon depression gradually became better organized as it moved steadily toward the west-northwest. The deep convection became more consolidated and cirrus outflow

became organized in a well-defined anticyclonic pattern, while the sea-level pressure slowly fell. Based on increased organization of the deep convection, sea-level pressures estimated at 1006 mb, and divergent outflow aloft (as indicated by animated water-vapor imagery) a Tropical Cyclone Formation Alert (TCFA) was issued at 0230Z on the 8th. The first warning on Tropical Depression (TD) 14W soon followed, valid at 0600Z the same day, based on a satellite intensity estimate of 30 kt (15 m/sec). This large TC intensified and was upgraded to Tropical Storm

Figure 3-14-1 Winnie nears its peak intensity of 140 kt (72 m/sec) as it approaches the Northern Mariana Islands (112133Z August visible GMS imagery).

Winnie (14W) with the 0600Z warning on 9 August. Winnie intensified quickly and became a typhoon by 0000Z on the 10th, and peaked at an intensity of 140 kt (72 m/sec) at 0000Z on the 12th (Figure 3-14-1). While still east of the Mariana Island chain. At 0600Z on the 12th, the system passed between the islands of Alamagan and Pagan. Winnie continued on its west-northwestward course and maintained an intensity of 140 kt (72 m/sec) for 24 hours, then began to slowly weaken as it approached the Ryukyu Islands. By 14 August, Winnie showed signs of developing concentric wall clouds which became more distinct on 15 and 16 August. As the typhoon passed through the Ryukyu Islands on 17 August, the inner wall cloud began to dissipate as the large-diameter outer wall cloud became well defined (see discussion below). Winnie moved across the East China Sea and made landfall on the eastern coast of China approximately 140 nm (260 km) south of Shanghai shortly before 1200Z on 18 August. The system passed across Manchuria and quickly dissipated as it moved into the mountainous terrain north of Vladivostok. The final warning was issued valid at 0000Z on the 19th. The remnants of Winnie were eventually observed to have recurved to the northeast.

III. DISCUSSION

a. Winnie's large-diameter outer eye wall cloud.

The well-defined eye of a mature TC is probably one of nature's most remarkable and awe-inspiring phenomena. In the Dvorak (1975, 1984) classification scheme, the intensity of a TC is estimated from several characteristics of satellite imagery. These include the distance of the low-level circulation center to the deep convection; the size of the central dense overcast; the cloud-top temperatures, the horizontal width of the eye wall cloud; and the width and extent of peripheral banding features. The basic TC pattern types identified by Dvorak are: (1) the "shear" pattern; (2) the "curved band" pattern; (3) the "central dense overcast" pattern; and, (4) the "eye" pattern. Of these pattern types, the "eye" pattern is probably the best known to the laymen.

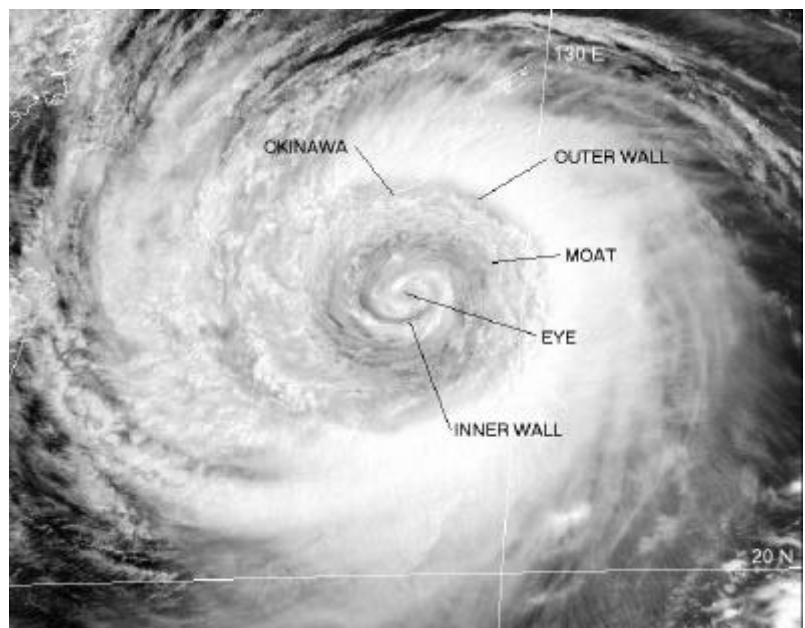


Figure 3-14-2 Winnie's outer wall cloud passes over Okinawa bringing typhoon-force winds as the small eye and inner wall cloud (within a relatively cloud-free moat) pass to the south. (170133Z August visible GMS imagery.) The black dot indicates the Kadena NEXRAD location.

The TC eye can be ragged or well-defined. In general, the more sharply defined the eye becomes on satellite imagery, the more intense the TC is likely to be. The average satellite-observed TC

eye diameter is between 30 and 45 nm (55 - 85 km) (Weatherford 1984). Eyes with diameters less than 30 nm (55 km) are considered to be small, while those with diameters greater than 45 nm (85 km) are considered to be large. In the Dvorak scheme, the intensity of a TC with a large well-defined eye is capped at 115 kt (59 m/sec), and the intensity of a TC with a large ragged eye is capped at 90 kt (46 m/sec), regardless of other characteristics observed on the satellite imagery. Some extremes of eye sizes include the small, 8-nm (15-km) diameter eye of Super Typhoon Tip (JTWC 1979 - observed by aircraft), and the radar-observed, large, 200-nm (370-km) diameter eye of Typhoon Carmen (JTWC 1960).

Some TCs, especially the intense ones, develop concentric wall clouds separated by a relatively cloud-free moat. In such cases, the outer wall cloud may contract while the inner one collapses in a process known as eyewall replacement. This has been discussed at length by Willoughby et al. (1982) and Willoughby (1990). These authors also note that TC eyes almost invariably contract during intensification so that smaller eyes and extreme intensity tend to be correlated. The Dvorak scheme has no special rules for concentric eyewall clouds. This is most likely because a cirrus overcast normally obscures the outer wall cloud in satellite imagery.

As Winnie moved toward Okinawa on August 16, a large outer rain band began to encircle the wall cloud that defined the eye. By the time the typhoon passed over Okinawa, the rainband had become a complete, 200 nm (370 km) diameter, concentric outer wall cloud (Figures 3-14-2 and 3-14-3).

The largest eye diameter ever reported by JTWC was that of Typhoon Carmen (JTWC 1960) as it passed over Okinawa. By coincidence, Winnie also passed over Okinawa. Carmen's eye diameter, as measured by the weather radar at Kadena Air Force Base was 200 nm (370 km), approximately the same diameter as Winnie's outer eyewall cloud. The 1960 Annual Typhoon Report commented: "Another feature quite unusual about this typhoon was the diameter of its eye. Reconnaissance aircraft frequently reported eye diameters of 100 [nm] [185 km], using as the basis of measurement, surface winds and pressure gradient. However, with respect to wall clouds surrounding the eye, radar photographs taken from the CPS-9 at Kadena AB show quite clearly that on 20 August, the eye had a diameter of approximately

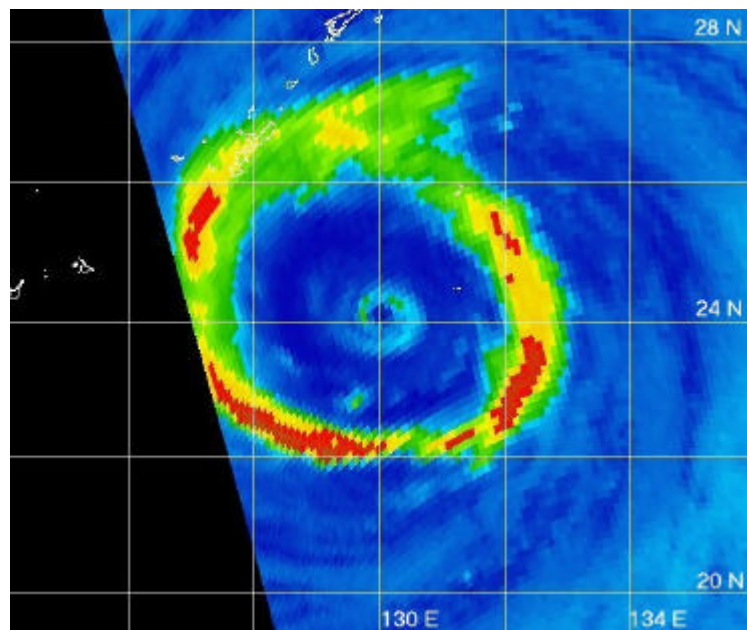


Figure 3-14-3 Winnie's outer wall cloud is nicely highlighted by microwave imagery. This is sensitive to regions containing precipitation-sized hydrometeors (especially large ice-phase particles). The eye and inner wall cloud are present but less distinct. (161311Z August horizontally polarized 85 GHz microwave DMSP imagery.)

200 [nm] [370 km]. The eye diameter of Carmen was probably one of the largest ever reported . . ." Winnie, like Carmen, was also viewed by radar at Kadena AB, a NEXRAD WSR 88D (Figure 3-14-4a,b).

As the outer wall cloud passed over Okinawa on 16 August, wind gusts of 82 kt (42 m/sec) were recorded (Figure 3-14-5) and the sea level pressure (SLP) fell to 964 mb (Figure 3-14-6). The center of the eye passed approximately 80 nm (150 km) south of the island. Doppler radar indicated 100-kt (51-m/sec) winds in the large outer eye wall in a layer from 3,000 ft (914 m) to 6,000 ft (1829 m). The NEXRAD base velocity product (Figure 3-14-4b) shows inbound wind speeds between 50 kt and 80 kt (26 m/sec and 41 m/sec) at an altitude of 8,000 ft (2438 m) above sea level on the eastern side of the inner wall cloud.

Although concentric wall clouds are not rare, especially for intense TCs, the extreme diameter of Winnie's outer eyewall cloud is an infrequent occurrence. Such large diameters are restricted primarily to the western North Pacific basin. In the Atlantic, TCs with large-diameter outer eye wall clouds have been observed, but not as large as these WNP examples. Such Atlantic storms include Allen (1980), Diana (1984), Gilbert (1988), and Luis (1995). These had outer eyewall clouds with diameters greater than 135 nm (250 km) and very small inner eyewall clouds with diameters less than 15 nm (28 km).

Sometimes typhoons which form in the monsoon trough of the western North Pacific generate very large circulations and eyes. The 370 km diameter of Winnie's outer eye wall cloud during passage over Okinawa is one of the largest ever observed in a TC. These cases are important because they define the most extreme possibilities of TC dynamics.

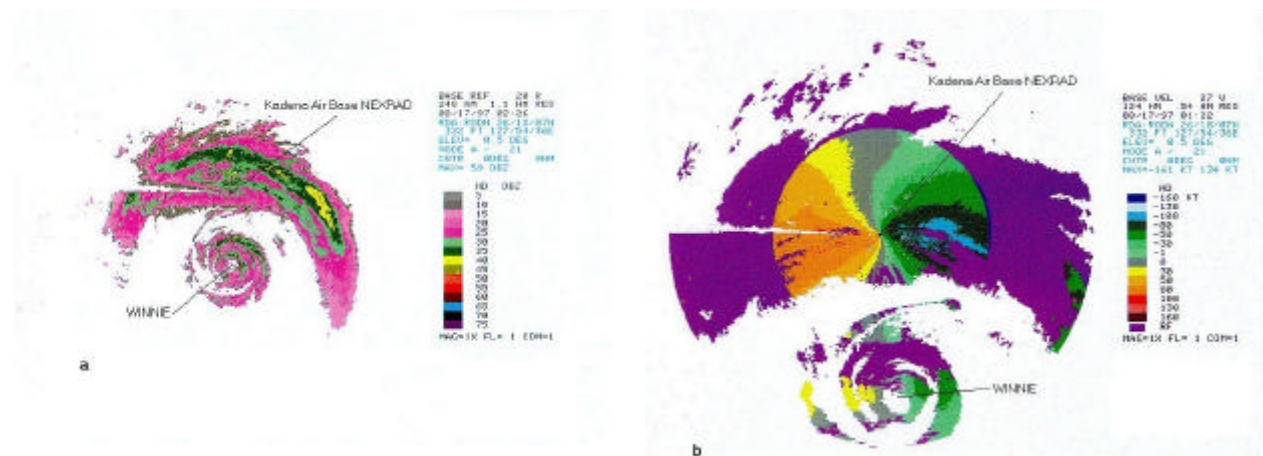


Figure 3-14-4 Winnie's outer wall cloud, and smaller inner wall cloud and eye, as depicted by the NEXRAD WSR 88D located near Kadena AB on Okinawa. (a) The base reflectivity at 170226Z August, and (b) the 170122Z August base velocity product. The NEXRAD is able to compute Doppler velocities within 125 nm (230 km) of the radar. The black dot (with arrow) shows the location of the NEXRAD in both panels.

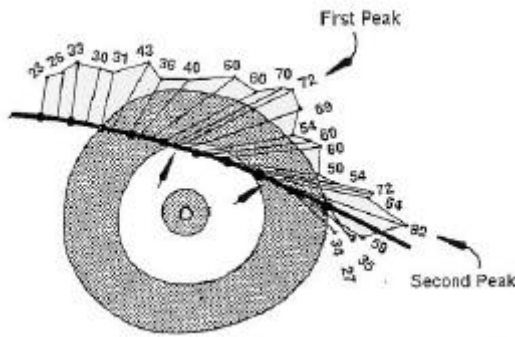


Figure 3-14-5 Wind reports from Kadena AB received at JTWC are plotted with respect to Winnie's cloud system (shaded regions). Winds are peak gusts in kt. Note that the peak gusts (indicated by arrows) at Kadena occur on the inward edge of the outer wall cloud in agreement with Jorgensen's (1984) synthesis of aircraft observations of the wind distribution in the large outer wall cloud of Hurricane Allen (1980). The small black dots along the indicated track are at 5-hour intervals from 160100Z to 172200Z August.

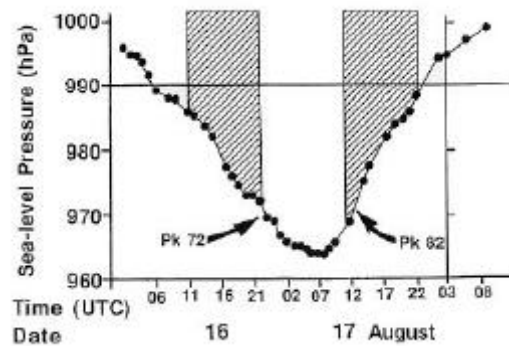


Figure 3-14-6 A time series of the sea-level pressure (SLP) recorded at Kadena AB as Winnie's outer wall cloud (hatched region) passed. Again, note the peak gusts occurring near the inner edge of the satellite observed outer wall cloud.

b. Winnie's Digital Dvorak (DD) time series

The magnitude of Winnie's Digital Dvorak (DD) numbers increased more rapidly than the warning intensity as the TC intensified on 11 and 12 August (a frequent occurrence). Winnie's series did not exhibit any obvious diurnal variations. Some typhoons exhibit a strong diurnal variation, while others (like Winnie) show little or none. Although not shown below, DD numbers were calculated for Winnie on 16 and 17 August when it possessed a very large diameter outer eye wall cloud by adapting the DD algorithm to use cloud-top temperature of the outer eye wall cloud to arrive at an intensity estimate. These DD numbers were observed to fluctuate between about 4.5 and 5.0. The corresponding intensity range of 77-90 kt

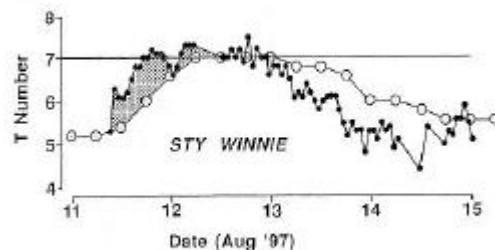


Figure 3-14-7 A time series of Winnie's hourly DD numbers (small black dots) compared with the warning intensity (open circles). As the TC was intensifying on 11 and 12 August, the DD numbers increase faster than the warning intensity (shaded region) -- a common behavior of the DD numbers. Note that the warning intensity is higher than the DD numbers as the TC begins to weaken, which is consistent with Dvorak's rule to delay the current intensity behind the decreasing data T-numbers.

(40-46 m/sec) fits well with synoptic reports from Okinawa (e.g., the 82 kt (42 m/sec) peak gust at Kadena, and the NEXRAD indications of 100 kt (51 m/sec) winds within the outer eyewall layer between 3,000 ft (914 m) and 6000 ft (1829 m)).

IV. IMPACT

As Winnie passed through the northern Mariana Islands, the populated islands of Guam, Rota, Tinian, and Saipan (well to the south of Winnie's track, but within its gale area) reported damage to crops and vegetation from winds and sea-salt spray. In Taiwan, 27 people were reported killed when an apartment building collapsed. Another 12 people were reported killed from mudslides, flooding and high wind. In mainland China, torrential rains and winds caused at least 25 deaths. Damage from wind and flooding was extensive.

